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Summary

THE BIG IDEA **Voltage is an "electric pressure" that can produce a flow of charge, or current, within a conductor.**

34.1 Flow of Charge

When the ends of an electric conductor are at different electric potentials, charge flows from one end to the other.

- Charge flows when there is a **potential difference**, or difference in potential (voltage), between the ends of a conductor.
- The flow of charge will continue until both ends reach a common potential. When there is no potential difference, there is no longer a flow of charge through the conductor.
- To attain a sustained flow of charge in a conductor, some arrangement must be provided to keep one end at a higher potential than the other.

34.2 Electric Current

A current-carrying wire has a net electric charge of zero.

- **Electric current** is the flow of electric charge.
- In solid conductors, the electrons carry the charge through the circuit because they are free to move throughout the atomic network. These electrons are called *conduction electrons*.
- In fluids, such as the electrolyte in a car battery, positive and negative ions as well as electrons may compose the flow of electric charge.
- Electric current is measured in **amperes**, for which the SI unit is symbol A. An ampere is the flow of 1 coulomb of charge per second.

34.3 Voltage Sources

Voltage sources such as batteries and generators supply energy that allows charges to move steadily.

- Something that provides a potential difference is known as a **voltage source**.
- The potential energy per coulomb of charge available to electrons moving between terminals is the voltage (sometimes called the *electromotive force*, or *emf*).
- Charges *flow* through a circuit because of an applied voltage *across* the circuit. Voltage doesn't go anywhere, for it is the charges that move. Voltage causes current.

34.4 Electric Resistance

The resistance of a wire depends on the conductivity of the material used in the wire (that is, how well it conducts) and also on the thickness and length of the wire.

- The amount of charge that flows in a circuit depends on the voltage provided by the voltage source. The current also depends on the resistance that the conductor offers to the flow of charge—**the electric resistance**.
- The resistance of some materials becomes zero at very low temperatures, a phenomenon known as **superconductivity.**
- Electric resistance is measured in units called **ohms.**

34.5 Ohm's Law

Ohm's law states that the current in a circuit is directly proportional to the voltage impressed across the circuit, and is inversely proportional to the resistance of the circuit.

- The relationship among voltage, current, and resistance is called **Ohm's law**. In short, current = voltage/resistance.
- The relationship among the units of measurement for current, voltage, and resistance is: 1 ampere = 1 volt/ohm.

34.6 Ohm's Law and Electric Shock

The damaging effects of electric shock are the result of current passing through the body.

- From Ohm's law, we can see that a damaging electric current depends on the voltage applied, and also on the electrical resistance of the human body.
- The resistance of the human body depends on its condition and ranges from about 100 ohms if it's soaked with salt water to about 500,000 ohms if the skin is very dry.
- Drops of water that collect around on/off switches of devices such as a hair dryer can conduct current to the user. Handling electric devices while taking a bath is extremely dangerous.
- If a bird is perched on a highline wire, the bird will not receive a shock unless there is a *difference* in potential between one part of its body and another part.
- Mild shocks occur when the surfaces of appliances are at an electrical potential different from that of the surfaces of other nearby devices.

34.7 Direct Current and Alternating Current

Electric current may be DC or AC.

- **Direct current** is a flow of charge that *always flows in one direction*. Electrons always move through the circuit in the same direction, from the repelling negative terminal and toward the attracting positive terminal.

- **Alternating current** (AC) is electric current that repeatedly reverses direction. Electrons in the circuit move first in one direction and then in the opposite direction, alternating back and forth about relatively fixed positions.
- Nearly all commercial AC circuits in North America involve voltages and currents that alternate back and forth at a frequency of 60 cycles per second. This is 60-hertz current.
- Voltage of AC in North America is normally 120 volts. Power transmission is more efficient at higher voltages, so Europe adopted 220 volts as its standard.
- The primary use of electric current, whether DC or AC, is to transfer energy quietly, flexibly, and conveniently from one place to another.

34.8 Converting AC to DC

✓ **With an AC-DC converter, you can operate a battery-run device on AC instead of batteries.**

- In addition to a transformer to lower the voltage, an AC-DC converter uses a **diode,** a tiny electronic device that acts as a one-way valve to allow electron flow in only one direction. Since alternating current vibrates in two directions, only half of each cycle will pass through a diode. The output is a rough DC, off half the time.
- To maintain continuous current while smoothing the rough DC, a capacitor is used.

34.9 The Speed of Electrons in a Circuit

✓ **In a current-carrying wire, collisions interrupt the motion of the electrons so that their actual *drift speed*, or *net speed* through the wire due to the field, is extremely low.**

- Energy is transported through the connecting wires at nearly the speed of light. The electrons that make up the current, however, do not move at this high speed.
- A pulsating electric field can travel through a circuit at nearly the speed of light. The electrons continue their random motions in all directions while simultaneously being nudged along the wire by the electric field. Conduction electrons are accelerated by an electric field.
- Before the electrons gain appreciable speed, they “bump into” the anchored metallic ions in their paths and transfer some of their kinetic energy to them. This is why current-carrying wires become hot.
- In an AC circuit, the conduction electrons don’t make any net progress in any direction. They oscillate rhythmically to and fro about relatively fixed positions. When you talk to your friend on a conventional telephone, it is the *pattern* of oscillating motion that is carried across town at nearly the speed of light.

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34.10 The Source of Electrons in a Circuit

✓ The source of electrons in a circuit is the conducting circuit material itself.

- When you plug a lamp into an AC outlet, *energy* flows from the outlet into the lamp, not electrons. Energy is carried by the electric field and causes a vibratory motion of the electrons that already exist in the lamp filament.
- When you are jolted by an AC electric shock, the electrons making up the current in your body originate in your body. Electrons do not come out of the wire and through your body and into the ground; energy does.

34.11 Electric Power

✓ Electric power is equal to the product of current and voltage.

- **Electric power** is the rate at which electrical energy is converted into another form such as mechanical energy, heat, or light. In equation form, electric power = current × voltage.
- If the voltage is expressed in volts, and the current in amperes, then the power is expressed in watts: 1 watt = (1 ampere) × (1 volt).
- A *kilowatt-hour* represents the amount of energy consumed in 1 hour at the rate of 1 kilowatt, or 1000 watts.